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DEVELOPMENT OF THE NERNST LAMP IN AMERICA.

—BY—

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Manager, Nernst Lamp Co.

Presented at the 18th Annual Convention of the American Institute of Electrical Engineers, Buffalo, August 23, 1901.

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A paper presented at the 18th Annual Convention of the American Institute of Electrical Engineers, Buffalo, August 23d, 1901. President Steinmetz in the Chair.

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DEVELOPMENT OF THE NERNST LAMP IN AMERICA.[1]

BY ALEXANDER JAY WURTS.

It was in 1897 that Mr. Henry Noel Potter, while in the employ of Mr. Westinghouse, at Goettingen, became acquainted with the Nernst lamp. Early in 1898, Dr. Nernst, Mr. Potter and an assistant came to East Pittsburg at Mr. Westinghouse's request and exhibited the new discovery. Mr. Westinghouse quickly recognized its great possibilities and directed the writer to prepare for its commercial introduction. A happy choice brought Mr. Marshall W. Hanks to my assistance. Mr. Potter returned to Goettingen to study some of the details of the work. In June, 1899, Mr. Edward Bennett joined us, as did also Mr. Frederick M. Goddard a month or two later, who had been assisting Mr. Potter in Germany, but unfortunately in December of that year, Mr. Goddard contracted a violent cold from which he never recovered. In February, 1900, Mr. Murray Charles Beebe joined us and in August of the same year, Dr. Max von Recklinghausen.

I have thus briefly introduced the characters who have worked upon the Nernst lamp in America and without whose names its

1. EXPLANATORY NOTES.—The Hefner unit of candle power has been adopted in this paper so that ready comparisons may be made with results obtained on the Nernst lamp in European countries.

Names of Parts in the Nernst Lamp:—The "glower" is the filament or light-giving body. The "ballast" is a steadying resistance connected in series with each glower. The "holder" is the removable piece containing glowers and heaters. The "heater-porcelain" is the porcelain disk in the holder immediately back of the heater. The "heater-case" is a small glass globe used in the six-glower and thirty-glower lamps.

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history would be incomplete; my only regret being that these gentlemen are not all present on this occasion to share in the pleasure of announcing to the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS the results of our work upon the Nernst lamp.

THE GLOWER.

It is not my purpose to describe the details of our experiments, but rather to give the results of our work. Let us begin with the glower, so named to distinguish it from the filament of the incandescent lamp.

Our standard 220-volt glower is about 25 millimetres long and .63 of a millimetre in diameter. It is made by expressing from a die a dough made of the rare earths mixed with a suitable binding material, cutting the porcelain-like string thus made into convenient lengths, drying, roasting, and finally attaching lead wires. This sounds very simple, but the making of glowers is an art not easily acquired; it is the result of long and painstaking investigation, particularly with reference to the terminal connection between the glower and lead wire. This connection, as Dr. Nernst made it, consisted of a few turns of platinum wire wound around each end of the glower, the convolutions being finally pasted with cement. This forms a successful and effective terminal, but the shrinkage of the glower ends, away from the convolutions of platinum wire sometimes causes the contact to deteriorate, resulting in the weakening and early destruction of the glower near the terminal. In the Hanks terminal, these conditions are reversed. A platinum bead is embedded in the end of the glower in such a manner that any tendency to shrink on the part of the glower material can result only in tightening the contact and thereby maintaining intimate union between the platinum bead and the glower. It is, then, a simple matter to fuse lead wires to the embedded platinum beads.

The glower, as you all know, is a non-conductor when cold, becoming, however, a conductor when heated. It is also an electrolyte; but it may be fairly stated that this phenomenon is not clearly, if at all, understood. Oxygen, however, seems to be necessary, or at least desirable, for its successful operation. As might be expected, no electrolytic action is apparent when operating with alternating current. With direct current, the electrolytic action is quite marked, resulting in a black deposit on the negative end of the glower, which spreads gradually from

the negative toward the positive terminal. As this deposit increases, the voltage of the glower changes somewhat, and the candle power and efficiency fall off, owing to the poor light-emitting properties of the blackened portion. The life of the glower on alternating current is about 800 hours; with the same glower on direct current, it is considerably less than this. There are, however, radical improvements being made in direct current glowers.

A glower burns at a higher efficiency in its own heat, that is, in a globe, than it does in the open air. We shall refer again to

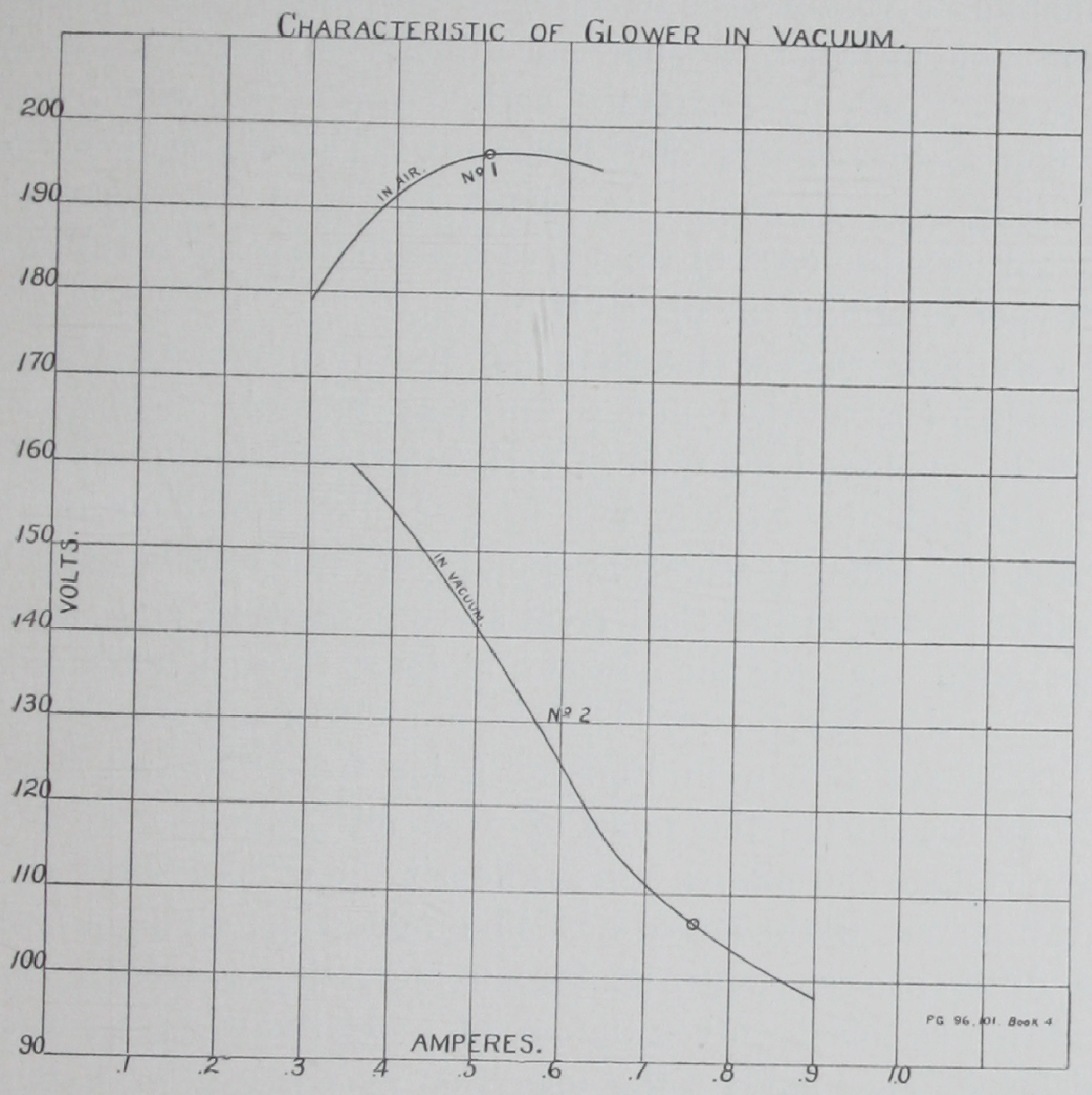

FIG 1.

this feature in connection with the multiple glower lamp. The glower is about as strong as a piece of porcelain of the same size, and it is difficult to break a short section. The terminals of a glower give off platinum black, which deposits on the globe; and although this cannot be wiped off with a cloth, it is easily removed in a variety of ways, so that the globe may be considered a permanent fixture in the lamp, and, for that reason, may assume fancy designs. When properly made, the voltage of a glower

changes but slightly during its life, the tendency being to rise from two to four per cent. in 800 hours. For a short time before rupture, the voltage rises rapidly until the glower is broken.

The characteristic of a glower with reference to voltage and current is remarkable, and has given rise to the necessity of a steadying resistance. As the current in the glower is increased, the voltage across its terminals rises, at first rapidly, and then more and more slowly to a maximum, beyond which it again drops off with increasing rapidity as the current and resulting temperature through the glower continue to increase. Beyond the point of maximum voltage, the decrease in resistance of the glower is so rapid as to make the current difficult of control. In fact, without a steadying resistance, such a conductor would rapidly develop a short-circuit and flash out. The characteristic of a Nernst glower is shown in curve 1, Fig. 1, the small circle situated near the crest of the curve representing the point of 1.76 watts per candle in the open air.

In studying the characteristics of the glower and seeking for methods of operation under the best possible conditions, we naturally exploited the field in various gases including a vacuum, and although the experiments in this direction have not been exhaustive from a scientific standpoint, the results have been negative as far as practical results are concerned, and have demonstrated that for the present, at least, there is nothing to be gained in this direction. The vacuum curve and corresponding air curve are shown in Fig. 1. Aside from the fact that the vacuum has shifted the point of 1.76 watt efficiency to a much lower voltage and higher current density, it will be observed that all the points of the curve now lie on one side, giving a decreasing difference of potential for an increasing current. Such a condition as this involves the use of a relatively large steadying resistance, and renders the operation of the glower inefficient. Fig. 2 shows the nitrogen curve with corresponding air curve, and it will be observed, as in the case of the vacuum, that this gas has also rendered necessary a large steadying resistance and has thereby lowered the available efficiency of the glower. In Fig. 3, we have both the oxygen and hydrogen curves to compare with the air curve. It is interesting to note how closely the oxygen and air curves compare with each other, while the hydrogen curve shows characteristics similar to that of the vacuum curve requiring a large steadying resistance.

There is an interesting phenomenon connected with glowers operating in a space free from oxygen, and which seems to be especially pronounced when operating in a vacuum. Where oxygen is excluded, the glower seems to be sluggish and to respond but slowly to changes in line voltage. The curves in Fig. 4 show this sluggish action in a vacuum. The line voltage is indicated by a dotted line in the upper part of the diagram, beginning with 270 volts. The upper solid curve shows the change of current value during a lapse of time indicated in minutes; while the lower curve shows the change in voltage on the glower during the same interval. Previous to this test, the glower had been run at .25 of an ampere for half an hour, after which the

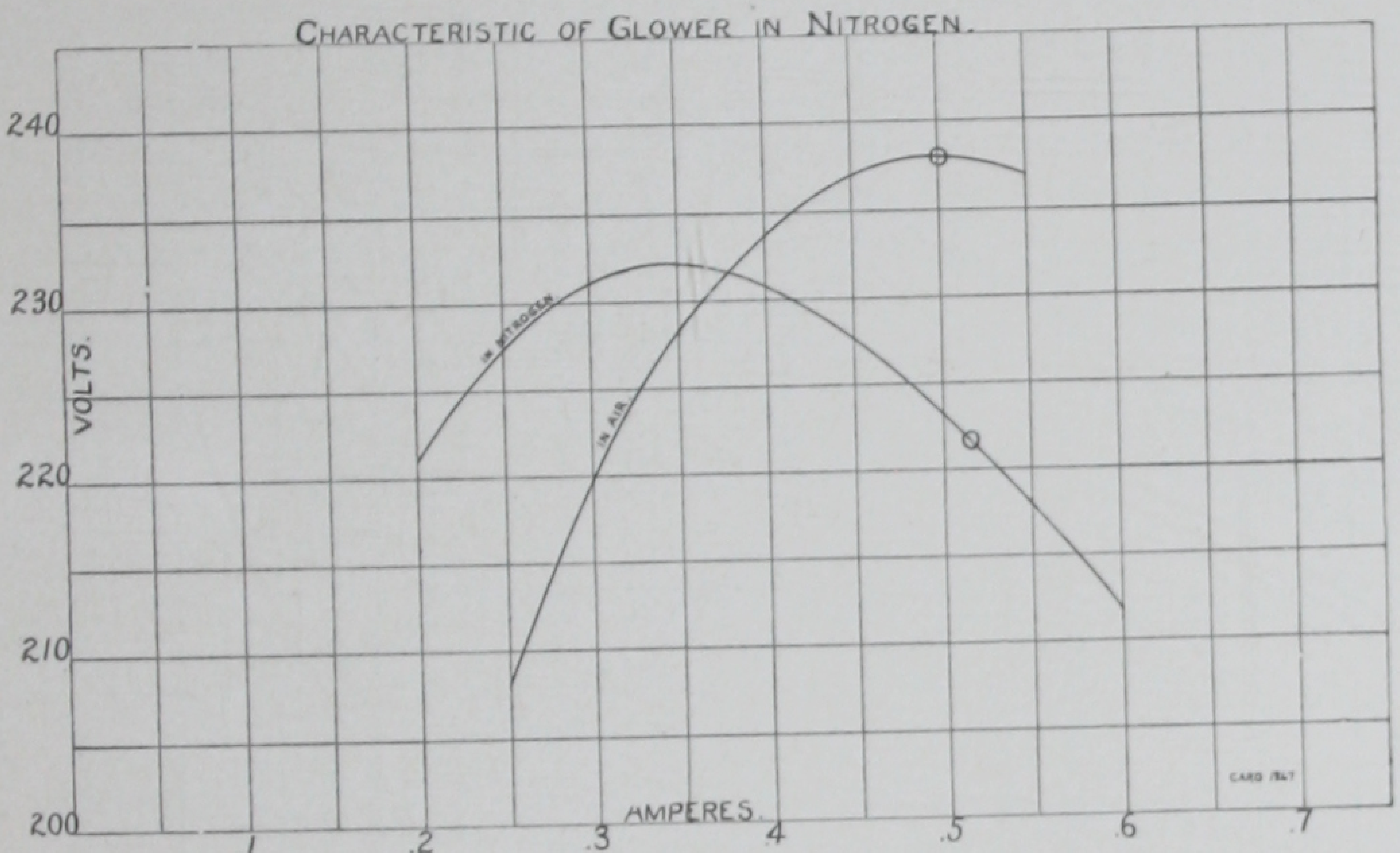

FIG. 2.

line voltage was raised 20 volts and the current values and differences of potential on the glower were taken at intervals for ten minutes, resulting in the curves shown. Shortly after the completion of this test, the line voltage was lowered 20 volts, when the glower again adjusted itself slowly to the new conditions, and returned to its original current and difference of potential. In air, the glower would have responded almost immediately to similar changes in line voltage. It is likely that the slight changes in both cases after the first minute are largely, if not entirely, due to the temperature correction of the resistance that was connected in series with the glower.

Steadying Resistance or Ballast.

The advantage to be gained by the use of a steadying resistance which would enable the glower to be operated efficiently at a point on or beyond the crest in the characteristic curve, was well recog-

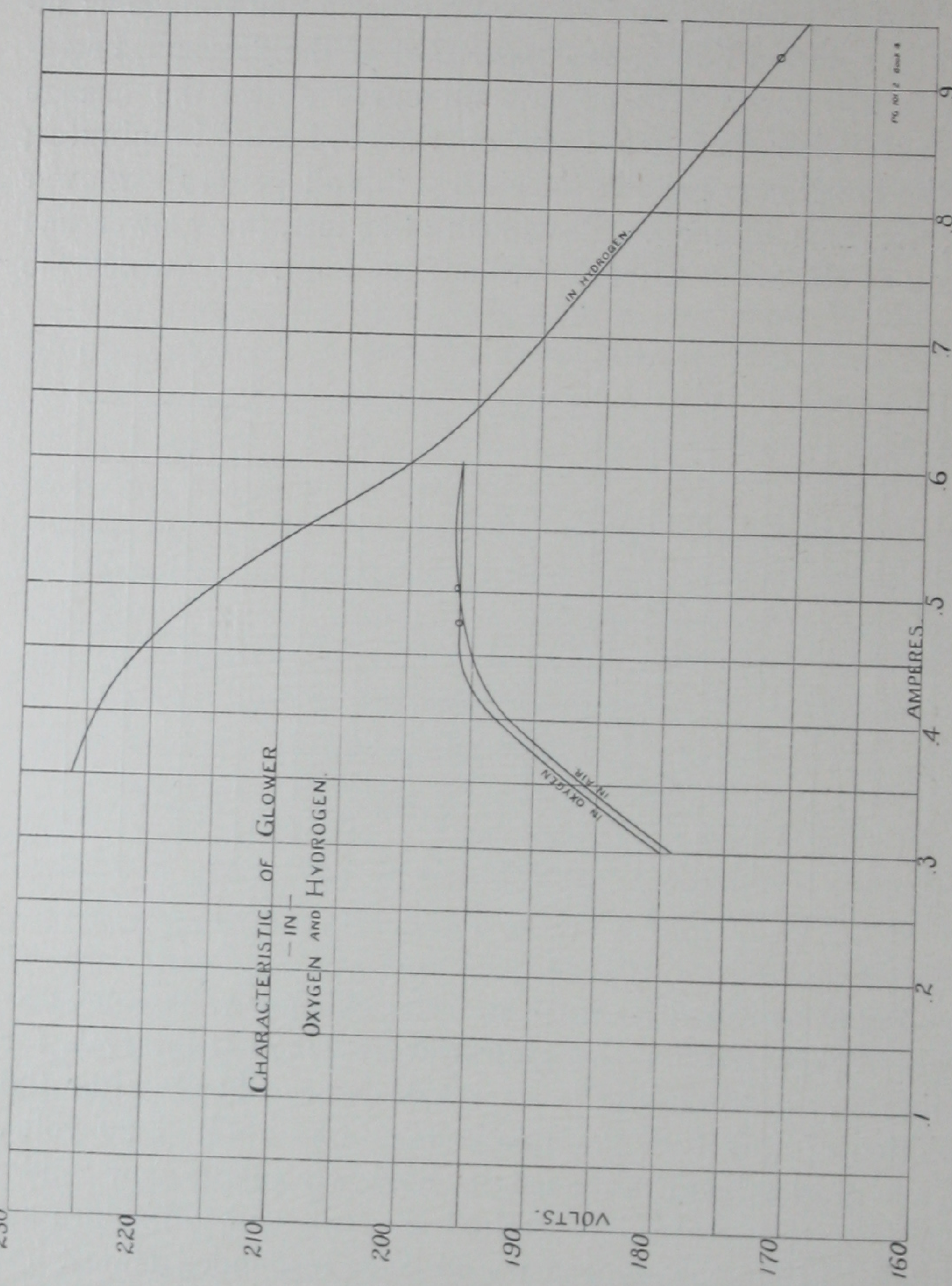

Fig 3.

nized. To accomplish this under all conditions of commercial use, and with as little loss as possible under normal conditions, the steadying resistance should have as large a positive temperature correction as possible and this temperature correction should always be immediately available. For example, if the glower were operated on or beyond the crest of the characteristic, the

current could obviously be controlled by a sufficiently large steadying resistance having no temperature correction, but such resistance would very materially decrease the net efficiency of the glower. On the other hand, if the resistance is assumed to have

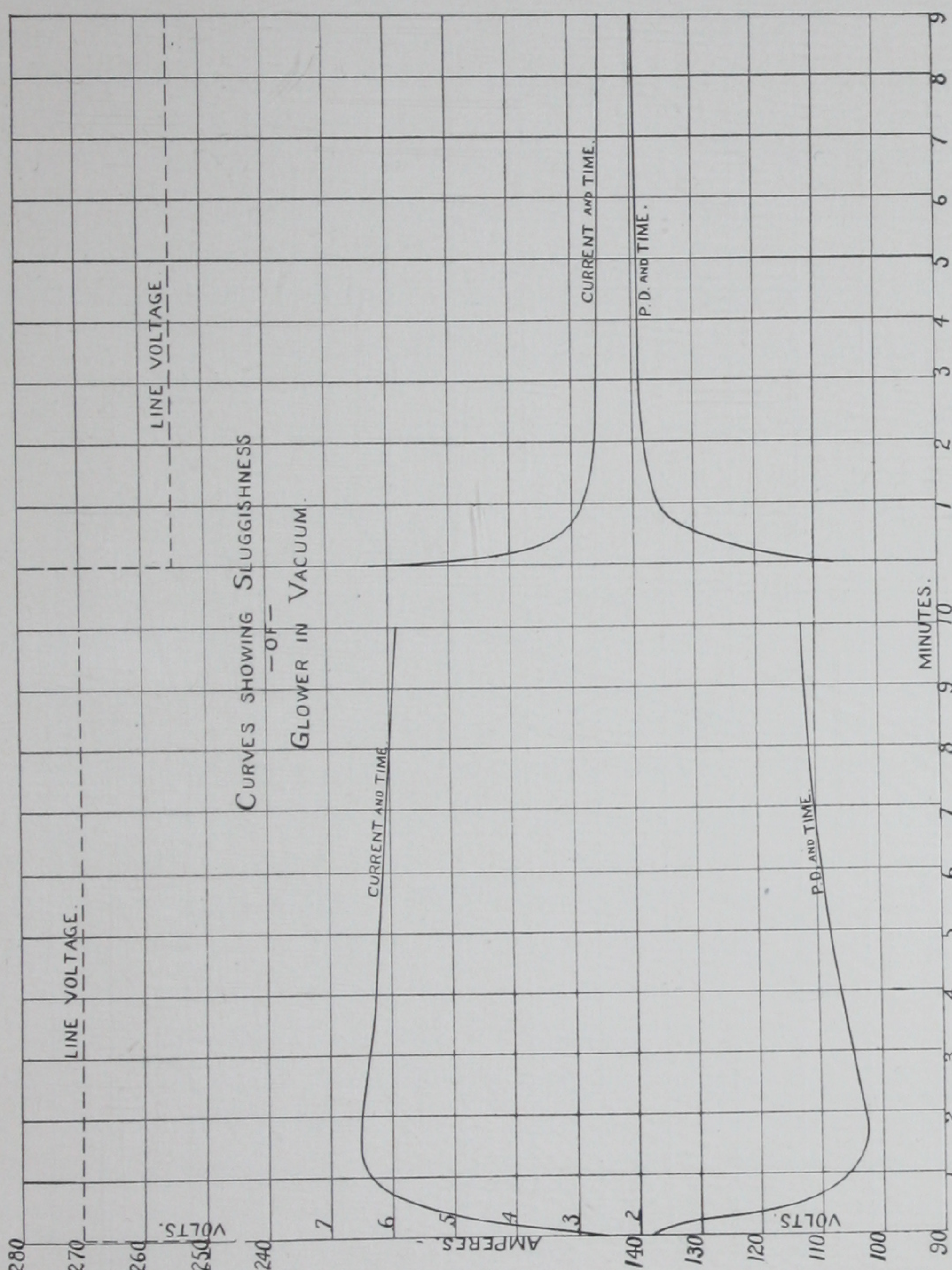

FIG. 4.

a high temperature coefficient, the necessary steadying resistance under normal conditions may be very much less than when no temperature correction is present, and then should there be an increase in electro-motive force above normal, the corrective power of the steadying resistance would be brought into play to check any abnormal flow of current through the glower; in other

words, to take up the additional voltage. As already stated, however, the temperature correction should be *immediately* available, for if it were not, the glower would "shoot over" when lighting above the normal pressure, that is, take more current at the start

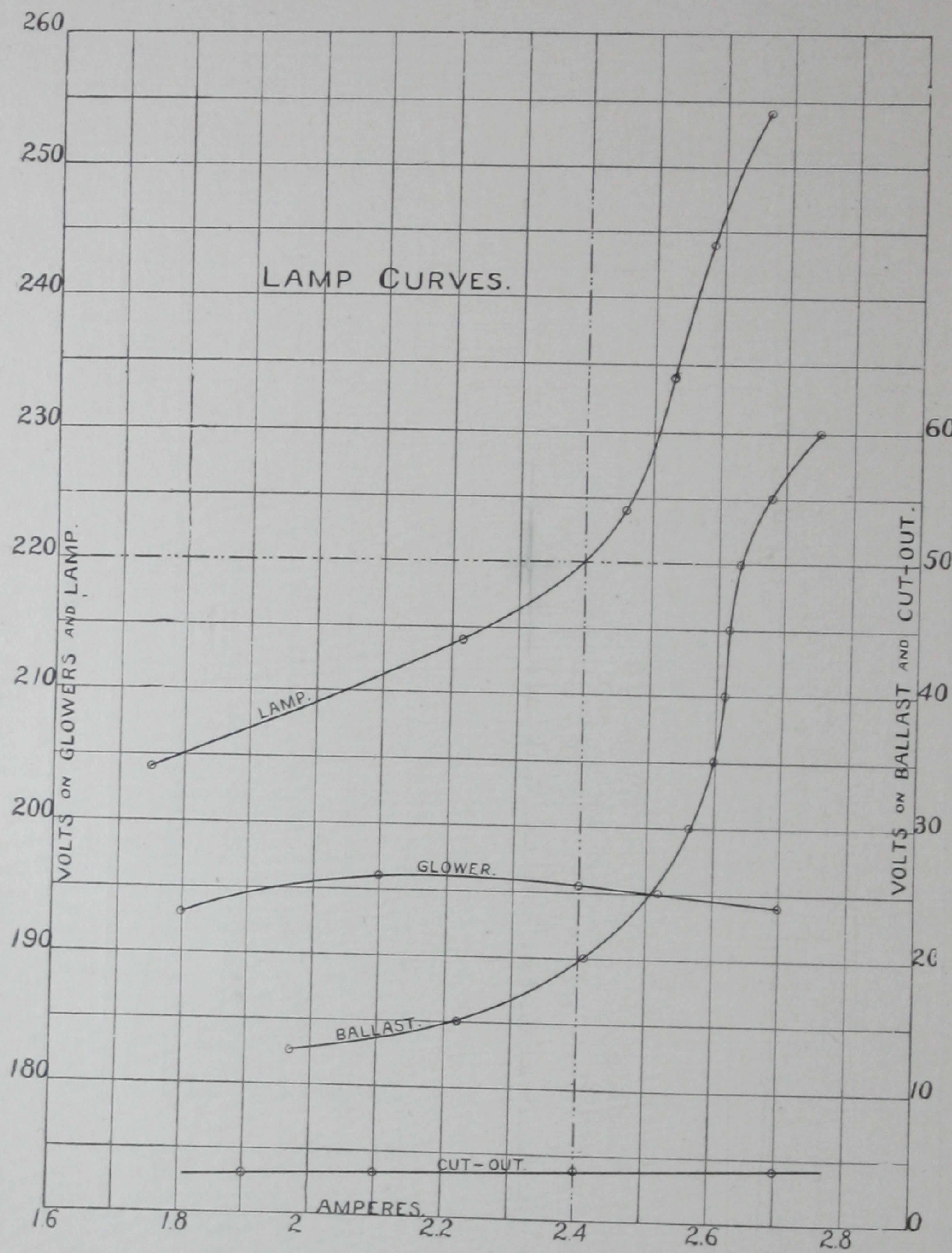

FIG. 5.

than it would a little later after the temperature correction of the steadying resistance had asserted itself. The same would also be the case with any sudden increase in the electromotive force applied to the glower, unless the corrective power of the steadying resistance were immediately available to check the current flow.

Mr. Potter has designed a steadying resistance or "ballast," as he has named it, which is certainly unique in construction and which meets in a very effective manner, the peculiar requirements of the glower. Iron wire is used on account of its high temperature correction, and by properly mounting this in a small glass tube filled with some inert gas, he has secured a ballast having at once a high corrective power with minimum resistance under normal conditions and oxygen being entirely excluded, the wire can readily be worked throughout the entire high corrective region without danger of destruction. This remarkable characteristic of the ballast is well shown in Fig. 5, from which it will be noticed that for a 10% rise in current, the resistance of the ballast increases 150%, so that a glower thus protected becomes at once operative throughout a wide range.

The Heater.

As already stated, the glower is a non-conductor when cold, becoming, however, a conductor when heated. For practical service in a lamp, therefore, it is necessary that some means be provided for heating the glower and bringing it to a conducting temperature. This topic could well form the subject of a paper by itself, but time will permit me to review but briefly the developments made in this direction. Some of the lamps which Dr. Nernst brought with him from Europe were fitted with electric heaters, while others were intended to be heated by an alcohol lamp or even by a match. The further refinements of the lamp imposed new and severe requirements upon the heater. It is therefore especially gratifying that we can announce the construction of a simple, satisfactory and effective heater, suited to the requirements of the latest forms of the lamp. The glower is lighted at a temperature of about 950° C., and it will be readily apparent that to acquire such a temperature quickly and without rapid destruction of the heater and adjacent parts, renders the selection of the materials a very serious problem. Platinum for the heater seems an undesirable expense in a commercial lamp, and although many attempts have been made to devise a cheap mineral heater, platinum still holds its own as the least expensive, the most durable, and altogether the most desirable material for this purpose. The actual expense, however, is not so serious, because when the platinum heater is burned out, the value of the scrap is nearly 90% of the original cost, and as the labor is almost negligible, the running cost of the heater is small.

As now constructed, the heater consists of a thin porcelain tube overwound with a fine platinum wire pasted with cement, the latter serving as a protection to the platinum wire from the intense heat of the glowers. These tubes are wound for 110 volts and are connected in pairs of two in series according to the service, the one, two, and three-glower lamps taking one pair, and the six-glower two pairs. These heater tubes are mounted on a porcelain support in such a manner as to afford easy access for repairs without removing the glowers. The life of the heater when running continuously is about 200 hours, or 133 hours

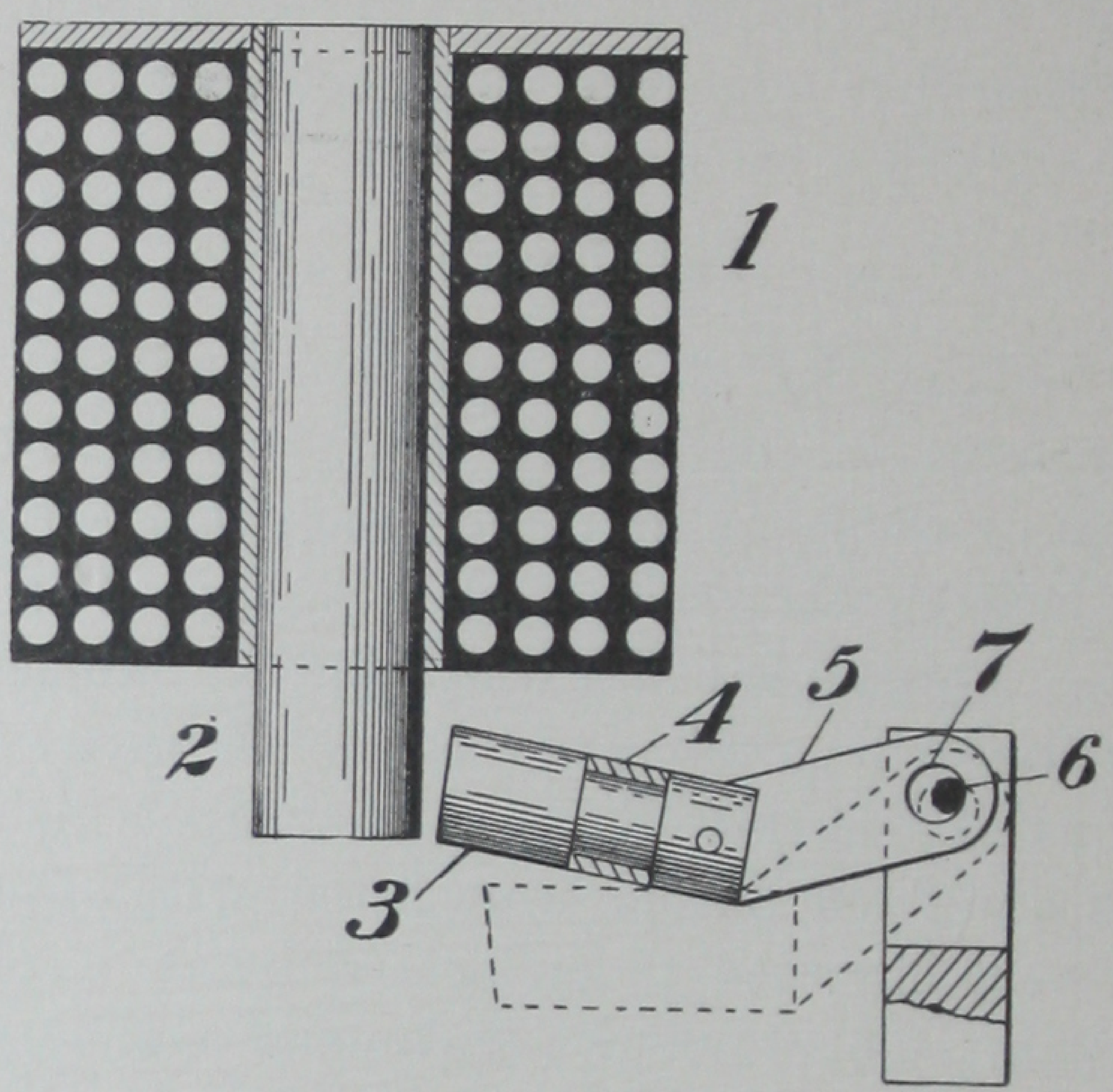

FIG. 6.

when the current is turned on and off 4,000 times at regular intervals. Inasmuch as the heater is not called into service for more than about 30 seconds to light the glowers, this would indicate a practically infinite life. In actual service, however, the heater remains in close proximity to the glowers and the high temperature to which it is thereby subjected causes a material decrease in its life. Nevertheless, the life of the heater is surprisingly long, probably several thousand lamp hours. The average life, however, cannot be definitely determined until a large number of lamps heve been operated over a very considerable period in general commercial lighting.

CUT-OUTS.

An automatic lamp requires a cut-out to disconnect the heater from the circuit as soon as the glower shall have lighted. This is another one of those details that Dr. Nernst developed and exhibited in some of his early lamps, but which we have sought to still further perfect and to adapt to the special types of lamp which we have constructed. The cut-out includes a coil, a moving member and a contact, all of which must function at a temperature of about 110° C. without possibility of failure. The coil must therefore be heat proof, the contact must not weld, and the moving member should not hum on alternating current. These requirements are severe, but they have all been met in a most effective and satisfactory manner by embedding the coil in cement, by making the contact of silver, and by suspending the moving member from a single point of support.

The latter feature of the cut-out is illustrated in Fig. 6; 1 is the coil; 2 the core; 3 the armature or moving member, which is round in section; 4 is a silver band which makes contact by gravity with two silver wires not shown, forming a V; 5 is a strip of sheet steel .007 of an inch thick, which is inserted into the armature and securely held by a pin; 6 is small steel rod or support for the armature; and 7 is a hole in the steel strip 5, somewhat larger in diameter than the pin 6, so that when the armature is attracted by the magnet, there is practically only a single point of contact between the strip 5 and the supporting pin 6. This construction has resulted in a cut-out which entirely avoids the humming sound so persistent in the ordinary types of alternating current apparatus.

LAMPS.

The lamps thus far developed are indicated in the following table:

Candle Power.	Voltage.	No. of Glowers.	Style.
50	110	1	Indoor
50	110	1	Outdoor
50	220	1	Indoor
50	220	1	Outdoor
100	220	2	Indoor
170	220	3	Indoor
400	220	6	Indoor
400	220	6	Outdoor
2000	220	30	Indoor

The main features are the same in all. The indoor lamps are provided with ornamental spun brass housings; the outdoor lamps with neat japanned cast-iron housings. Single glower lamps have single pole cut-outs, whereas all the multiple glower lamps are provided with double pole cut-outs, the reason for this difference being that the extremely high temperature in the immediate neighborhood of a number of glowers tends to establish leakage currents between the glowers and heaters, unless the latter be entirely disconnected from the circuit.

We will examine in detail the six-glower lamp as typical of all the others. This lamp is suspended from an eye-bolt which being removed, allows of immediate access to the inner parts. On removing the housing, we find that the ballasts are placed in a semi-circle around the cut-out, the arrangements of the parts being such as to make all easy of access. The connections are made with small aluminium plugs on the ends of the interconnecting wires which avoid the many familiar inconveniences associated with set screws. All the parts are mounted on porcelain; in fact, there is no combustible material whatever in the lamp. The heaters and glowers are attached to a removable piece or "holder," the design being such that the heaters backed by a porcelain disk are immediately above the glowers, resulting in the following advantages: Stagnation of heat from the heater, thereby lighting the glowers in minimum time; no shadows, nearly all the light being thrown downward where it is ordinarily most desired; stagnation of heat from the glowers whereby the latter are run in their own heat and therefore at a higher efficiency than they would otherwise. The glowers and heaters are attached to the binding posts of the holder by means of small aluminium plugs, so that the perishable members are always easily and conveniently interchangeable. The holder is provided with nine contact prongs, which, when the holder is pushed up into the lamp, automatically make the desired connections. These are shown in Fig. 7; 1 and 2 represent the line terminals; 3 the actuating coil; 4 and 4 the double pole cut-out; 5 the heater; 6 the glowers; and 7 the ballasts, there being, of course, one ballast for each glower. A small glass globe, called the "heater-case," is held by spring clamps around the glowers, the function of which is to retain the heat and thereby decrease the time of lighting as well as increase the efficiency of the glowers. In service, the "heater porcelain," which is the porcelain disk

immediately above the heater, becomes coated with a thin layer of platinum black, unless measures are taken to prevent it, and this not only decreases the illuminating power of the lamp, but if not removed, will in course of time become conducting and cause leakage of current. No simple means have been discovered for

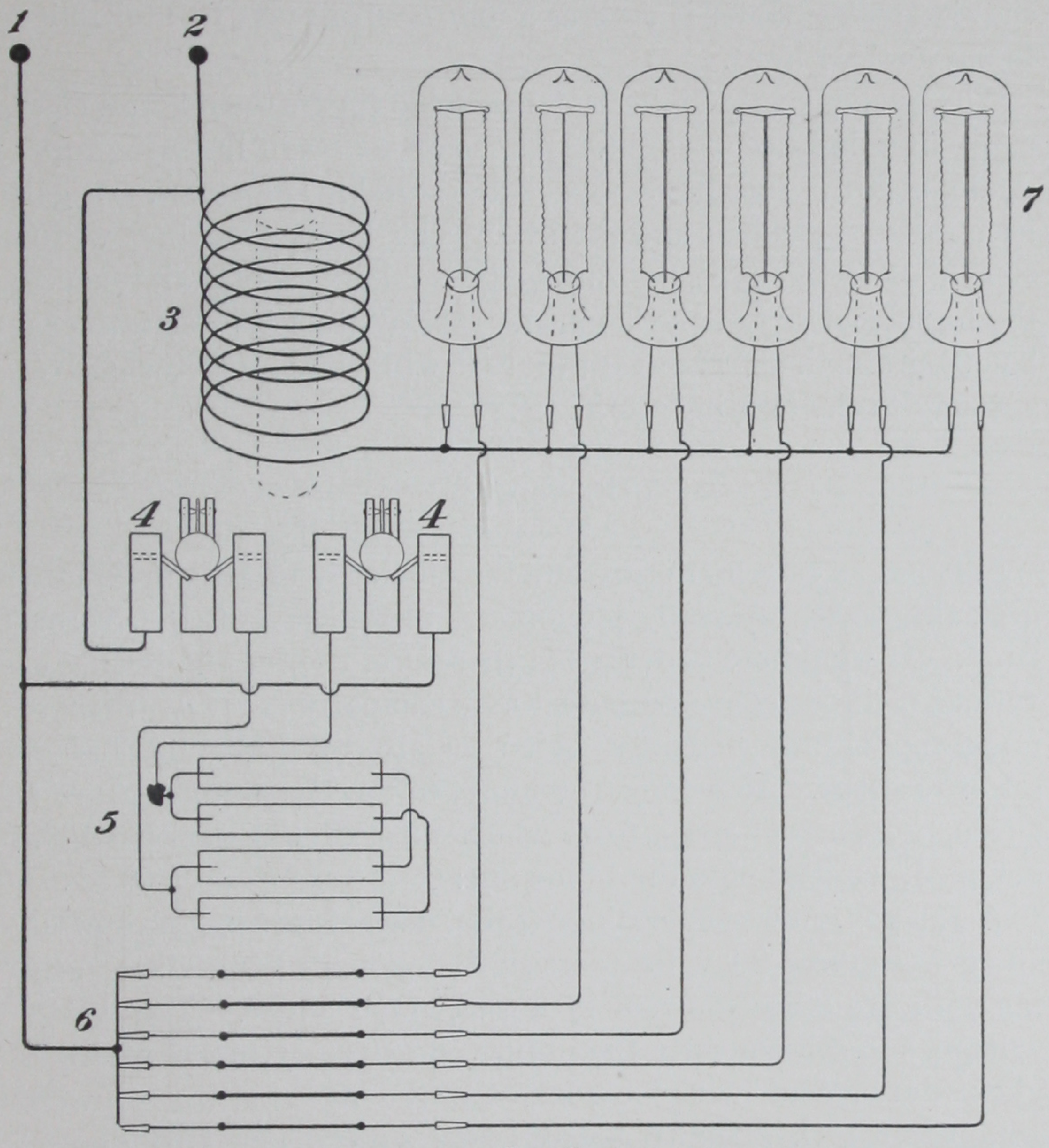

FIG 7.

removing the platinum black from the porcelain surface. This difficulty, nevertheless, has been avoided by coating the surface of the porcelain with a thin layer of white paste, which may be easily removed with a stiff brush or scraper. The platinum black now deposits on this coating, both of which may be removed together, leaving the fresh, white surface of the original porcelain to be recoated for further service; but even should the

platinum black be allowed to accumulate, all danger of leakage currents is avoided by surrounding the holes through which the lead wires pass, by small annular rings or grooves, it having been discovered that the platinum black will not deposit in these small spaces; the continuity of the platinum black surface between the lead wires is thereby interrupted. For higher candle powers, the six-glower holder is used as a unit and this may be multiplied to any desired limit.

The quality of the light is remarkable for its beauty and close approximation to daylight. All colors are seen in their proper shade, making the light especially desirable in stores, art galleries, drawing-rooms and the like. The absence of shadow, the steadiness of the light, the simplicity and low cost of maintenance, the high efficiency of the lamp, and the fact that it is operative on 3,000 alternations, are features that will commend themselves strongly to the lighting world.

Efficiency.

It is not an easy matter to state the efficiency of a light, and the difficulties are especially pronounced in the case of the Nernst lamp. It would seem desirable, therefore, to give the results of various methods of measurement and comparison rather than to make any definite statement based on any particular method or set of readings. Referring, therefore, to the six-glower, 220-volt, alternating current lamp, from which most of the data has been obtained, we may note the following:

A 220-volt glower operating at its normal current of .4 of an ampere, requires 20 volts more in the open air than when burning with five other glowers in a three-inch globe. The lower voltage and consequently the improved efficiency, when multiple glowers are placed in a globe, is due to the fact that the glowers are operating in a highly heated atmosphere. The efficiency of the six-glower lamp with clear heater case, but without the dome shade, is 1.2 watts measured in the direction of greatest intensity.

A more satisfactory statement will be found in the accompanying table giving the spherical and lower hemispherical efficiencies of the six-glower Nernst lamp, together with the corresponding figures for alternating current and direct current enclosed arc lamps:

					Mean Intensity in H. U.						Watts per Mean H. U.					
					Spherical.			Lower Hemisphere.			Spherical.			Lower Hemisphere.		
	Voltage.	Current.	Watts.	Power Factor.	Opal Outer.	Clear Outer.	Shade.	Opal Outer.	Clear Outer.	Shade.	Opal Outer.	Clear Outer.	Shade.	Opal Outer.	Clear Outer.	Shade.
6-Glower.	220	2.35	517	1.0	149*	—	147	240*	—	279	3.47*	—	3.5	2.15*	—	1.85
A. C. Arc.	110	6.29	417	.6	130	159	152	—	190	254	3.21	2.62	2.49	—	2.23	1.48
D. C. Arc.	110	4.9	539	1.0	177	207	—	—	272	—	3.03	2.60	—	—	1.98	—

An opal inner globe or heater-case was used in all cases except the *four* readings marked *.
*A clear heater-case and sandblasted spherical globe were used.

The arc lamp figures were taken from the Report of the Committee for Investigating the Photometric Values of Arc Lamps, read before the National Electric Light Association in May, 1900. Examining this table, it will be noticed that the spherical efficiency of both arc lamps is better than that of the Nernst. In the lower hemisphere, the Nernst is somewhat better than the alternating current arc and not as efficient as the direct current arc. When reflecting shades are used, the alternating current arc again has a slight advantage for the whole of the lower hemisphere; but if we disregard the mean of the lower hemisphere and consider the floor or desk illuminating power of the lamp, we find that the Nernst lamp has a very decided advantage over the enclosed alternating current arc; for example, if we consider the mean of the lowest 30° zone, the efficiency of the enclosed alternating current arc is 1.56 watts against one watt for the Nernst and the mean of the lowest 60° zone is for the enclosed alternating current arc, 1.45 watts against 1.23 watts for the Nernst.

Comparisons between the illuminating powers of the Nernst and incandescent lamps indicate a watt consumption in the Nernst lamp a little less than half of that in the incandescent for equal illumination. The superior quality of the Nernst lamp is also very marked both for reading purposes and for the correct determination of color.

A similar comparison between the illuminating power of the Nernst and enclosed alternating current arc lamps shows for an equal consumption of watts in the two lamps, a much superior

floor illumination for the Nernst lamp. Although the measurement shows a slightly better general illumination for the arc lamp, yet the quality and steadiness of the Nernst light, together with the entire absence of shadow, give an impression of decided superiority in favor of the Nernst.

The two sets of curves, Figs. 8 and 9, show interesting com-

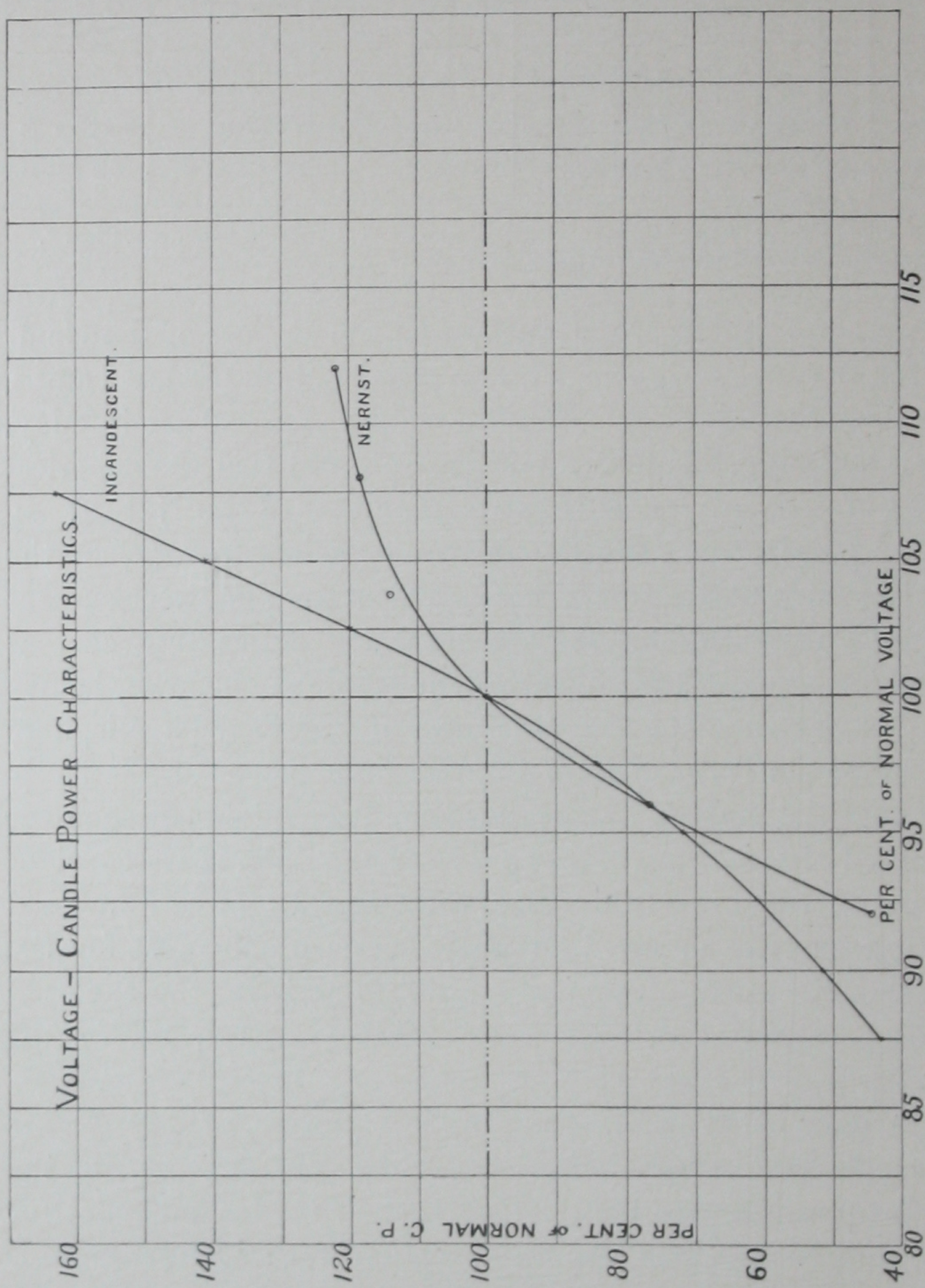

FIG. 8.

parisons between the Nernst and incandescent lamps under conditions of varying voltage. Fig. 8 shows the relative change in candle power and Fig. 9 the relative change in efficiency, all the variations in each case being given in per cent. of normal conditions. These curves are self-explanatory except as to the remark-

able steadiness of candle power in the Nernst lamp when forced above normal voltage. The feature is due to the great corrective power of the iron ballast.

At present our data regarding the effect of running Nernst lamps at different efficiencies is rather limited. Figures of this character require many readings under all kinds of conditions and it may be some time before these can be satisfactorily and definitely recorded, but roughly, it may be stated that the efficiency of the glowers falls but slightly during their natural life, provided the lamps are kept properly cleaned.

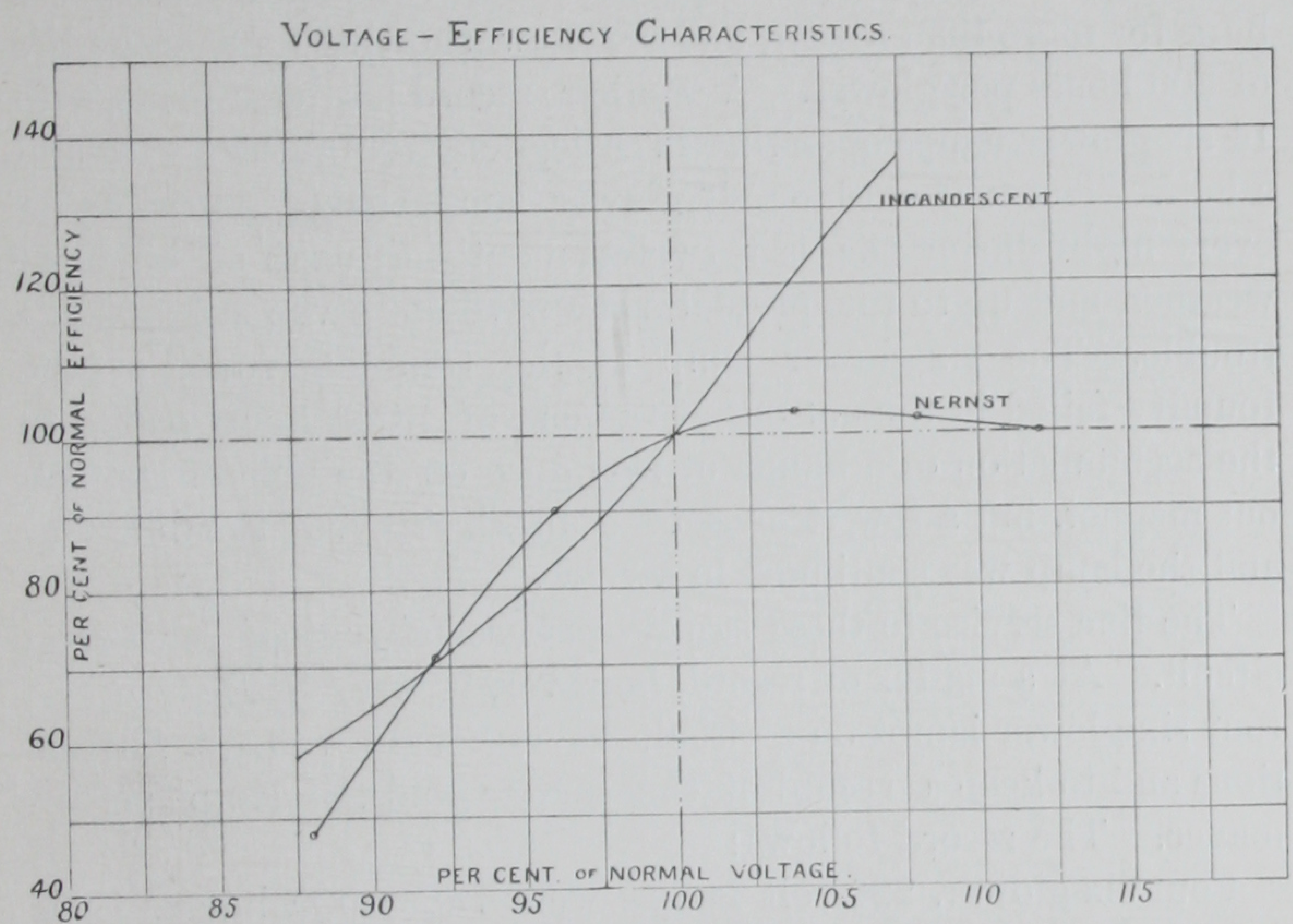

FIG. 9.

PERFORMANCE OF THE LAMP.

At the present writing, July 15th, there are in operation at East Pittsburg, 73 six-glower lamps, one three-glower and three single glower; in our laboratory and shop at Allegheny, 40 six-glower, 10 three-glower, and 21 single glower lamps; in the courtyard we have four outdoor six-glower lamps and in the tumbling room of the foundry, one outdoor six-glower lamp, all running on alternating current at 220 volts. In addition to these, there are 14 single glower direct current 110-volt lamps in Mr. Westinghouse's residence, making a total of something like 50,000 candle

power in and about Pittsburg. At the Pan-American Exposition, we have lighted the interior of the dome of the Electricity Building by festooning 92 six-glower lamps from a pendant chandelier consisting of a central lamp of 30 glowers and 2,000 candle power encircled with six lamps of the six-glower type; on the floor, variously distributed, there are 12 six-glower, 24 three-glower and eight one-glower lamps. These figures are intended to give some idea of the scale on which the Nernst lamp has been developed and the resources which have been placed at our disposal.

Seventeen six-glower lamps have been running at East Pittsburg for more than a year, and are now showing an average life of 800 hours per glower. A similar record has been made with 14 six-glower lamps operating in Allegheny for about a year and a half. The four outdoor six-glower lamps have been running every night during the last twelve months through all kinds of weather, and up to the present time have not given a moment's trouble. The six-glower lamp in the tumbling room of the foundry failed in the cut-out at the end of 1,000 hours owing to the accumulation of a bunch of iron dust on the pole of the cut-out magnet, but a few strokes of a brush removed the difficulty and the lamp was continued in service.

The line service to these lamps has been fairly good for a shop circuit. As a matter of record, however, it was decided to test four six-glower lamps on a circuit having wide voltage fluctuations and to keep a record of the service and the lamp performance. The record follows:

Four six-glower, 220-volt lamps were run 1,000 hours. The run was continuous with the exception of three periods per day of one-half hour each when the lamps were turned off. A record of the voltage was kept with a Bristol recording voltmeter. An inspection of the voltmeter cards show that these may be classified under three types. Of the first, there were 15 cards, indicating that the voltage did not rise higher than 229 volts and only remained there for a short period. Of the second type, there were 26 cards, in which the voltage reached a maximum of 232 volts, maintaining this for about four hours. Of the third type, there were four cards showing a rise of voltage to 237 and remaining at 235 for five hours. These cards show that the lamps have been tested on a circuit, pressure of which varies from 4% below to 7½%

above normal. There were no ballasts or heaters burned out during this run, nor did the lamps receive any attention or give any trouble.

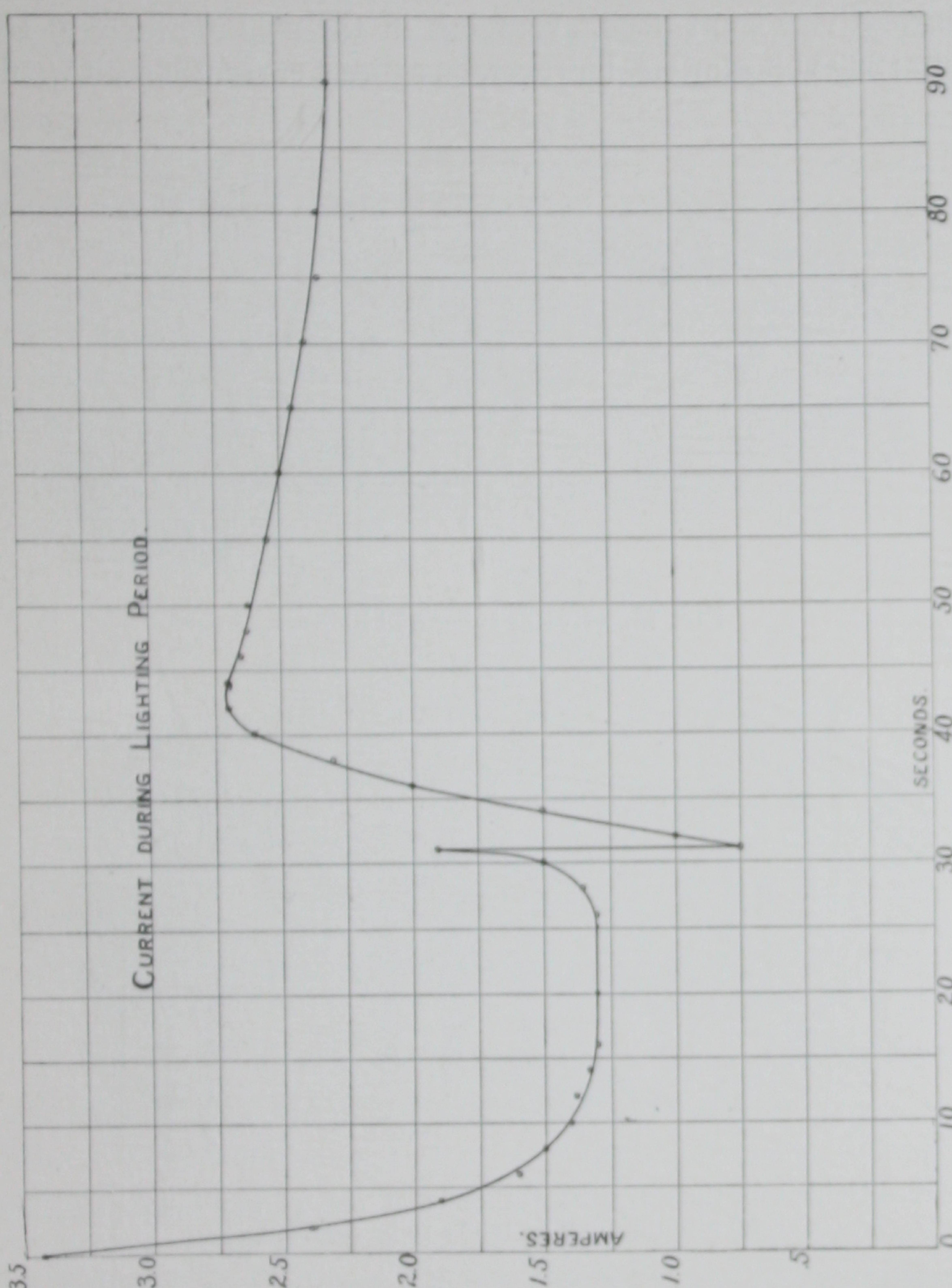

FIG. 10.

Of the 24 glowers in these lamps,

15 ran 1,000 hours;
6 ran 792 hours;
1 ran 580 hours;
2 ran 380 hours;

making an average of 890 hours.

The three, two and one-glower 220-volt, alternating current lamps have given equally satisfactory service, but the glowers in the 110-volt alternating current lamp are not quite so uniform in their performance and the same glowers on direct current are comparatively short lived, averaging in the neighborhood of 150 hours; 220-volt glowers, however, on a direct current circuit would

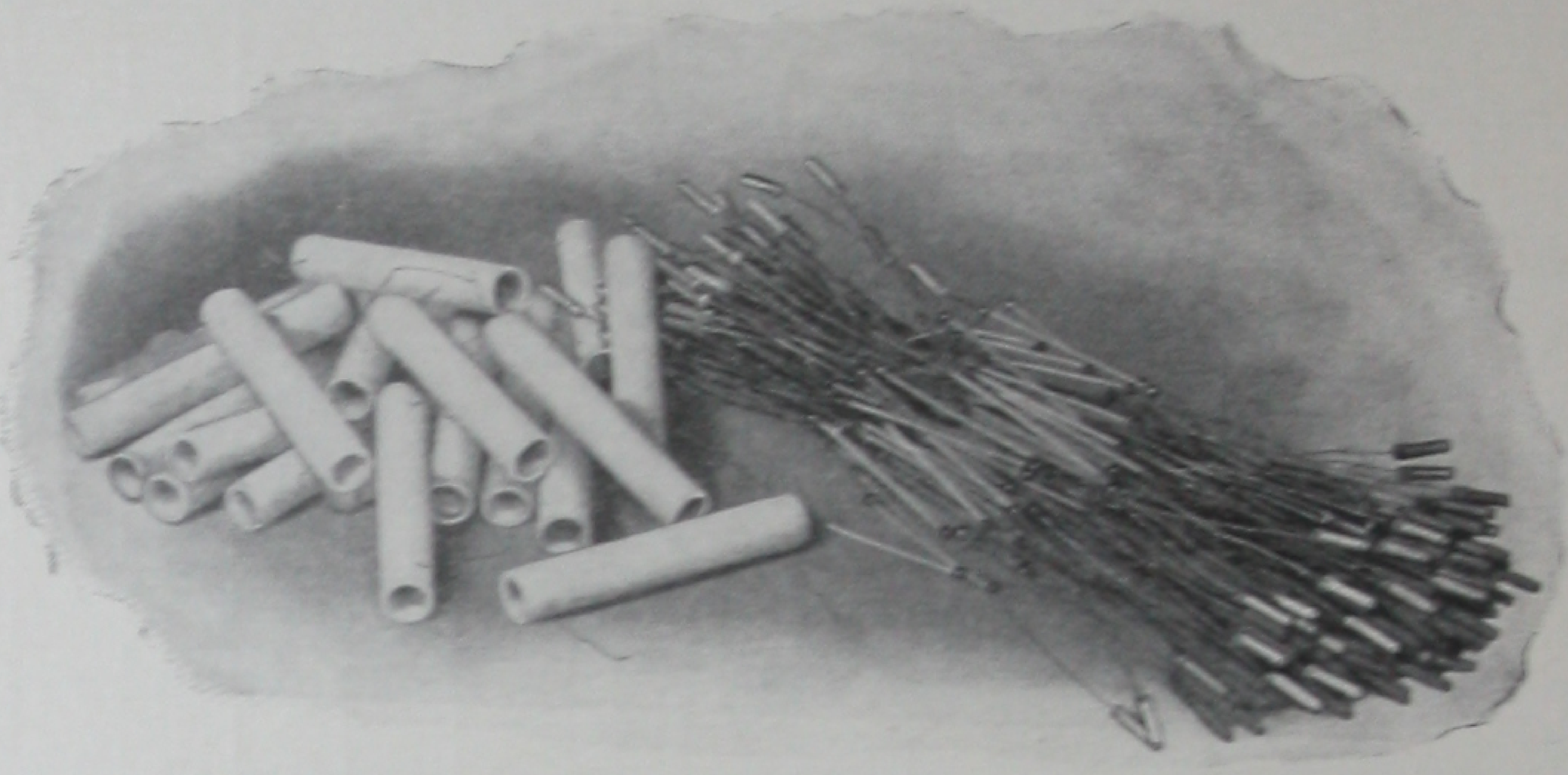

Fig. 11.—Heater tubes and glowers.

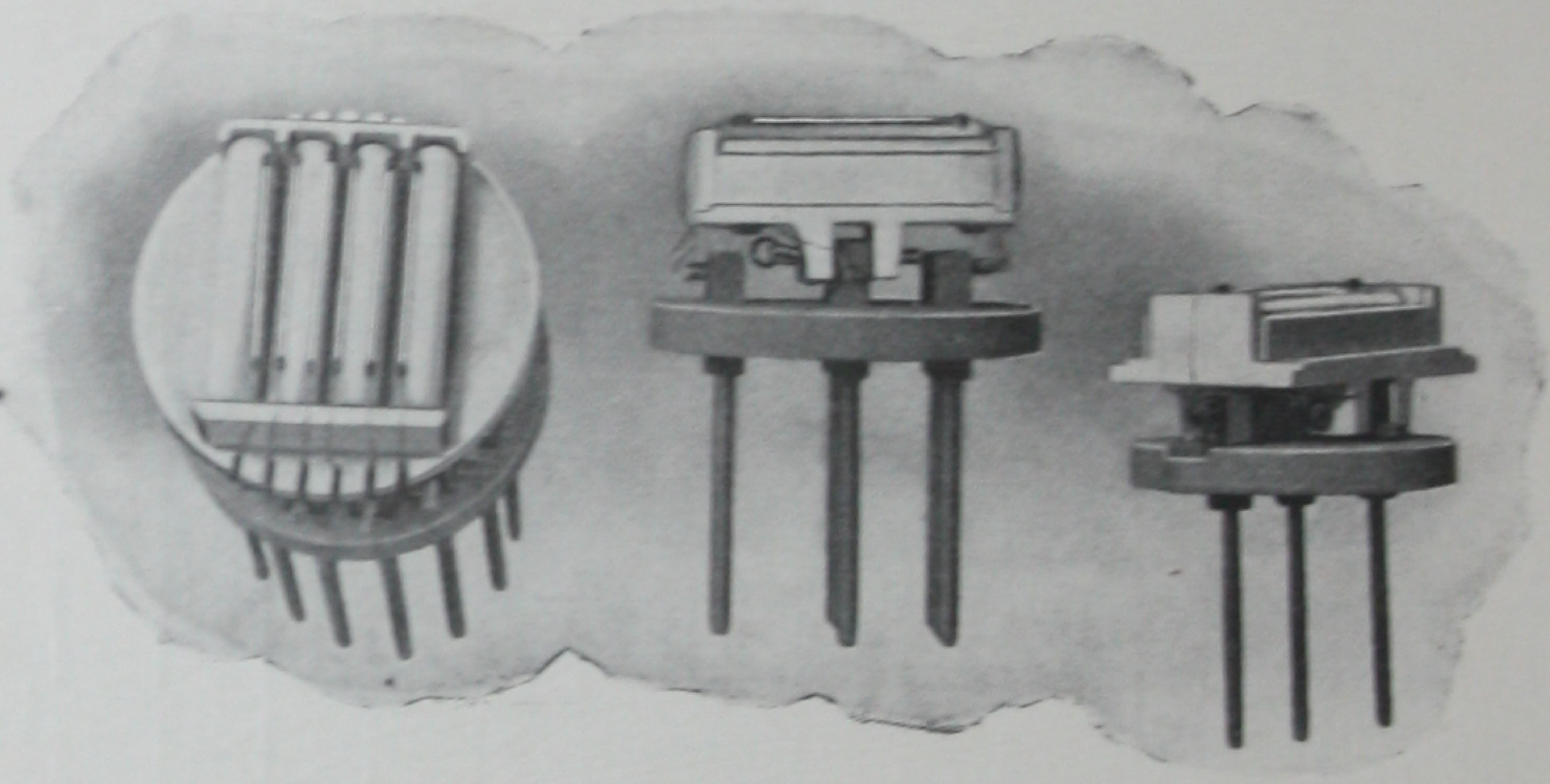

Fig. 12.—Holders for the six, two and three, and one glower lamps, showing an aluminium plug ready to be inserted.

last nearly double that time. At East Pittsburg, where a section of the Westinghouse works, about 350 feet long is lighted with 50 six-glower lamps suspended immediately above the traveling cranes, the features which strike me more forcibly than anything else are the beauty of the illumination and the total absence of shadow and flicker so intimately associated with the electric arc illumination in places of this character.

In connection with this topic, it will be interesting to note just what is going on in the lamp during the time of lighting, also during service under varying conditions of line voltage. Referring to Fig. 10, we have a curve showing the current taken by a six-glower 220-volt lamp during the lighting period. It will be noticed that as the current is turned on, there is a sudden rush of nearly 3.5 amperes through the heater, which, owing to the temperature correction of the platinum wire, is quickly reduced to about 1.3 amperes. At the end of 26 seconds, the first glower begins to light; at the end of 30 seconds, the second glower is lighted and the heater is cut out, the current dropping at once to .75 of an ampere; the remaining glowers then light rapidly until at the end of 40 seconds all the glowers are lighted. From this point on, there is a slight drop in the current until the lamp reaches its normal running temperature.

FIG. 13.—Parts of the single glower lamp.

Referring once more to Fig. 5, we find the current and voltage characteristics of the different elements in the lamp, and above these the characteristics of the lamp itself, the latter being the sum of the cut-out coil, the ballast and the glower. The lamp curve was taken from actual measurements and approximates very closely to the sum of the elements, the slight difference probably being due to some differences of temperature. The voltage scale for the cut-out and ballast curves will be found on the right hand side of the diagram; that of the glower and lamp on the left hand side. Your attention is now directed to the excellent characteristic of this lamp, and when we consider the severe conditions imposed by the glower characteristic, I think we are to be congratulated on the results which have been at-

tained. With a normal in the lamp of 2.4 amperes and 220 volts, it will be noticed that an increase of 14% in voltage causes but a 10% increase in current, resulting in a comparatively steady light and safe running conditions for the lamp in commercial service. A rise of 25% in the line voltage would burn out the ballasts in a very short time, but a rise of 10% for short periods does not seriously affect the life of either glower or ballast; a rise of 5% may be considered allowable for indefinite periods.

Repair and Maintenance.

When the lamps are first started, they require no attention. After 1,000 hours, however, the renewals become fairly regular

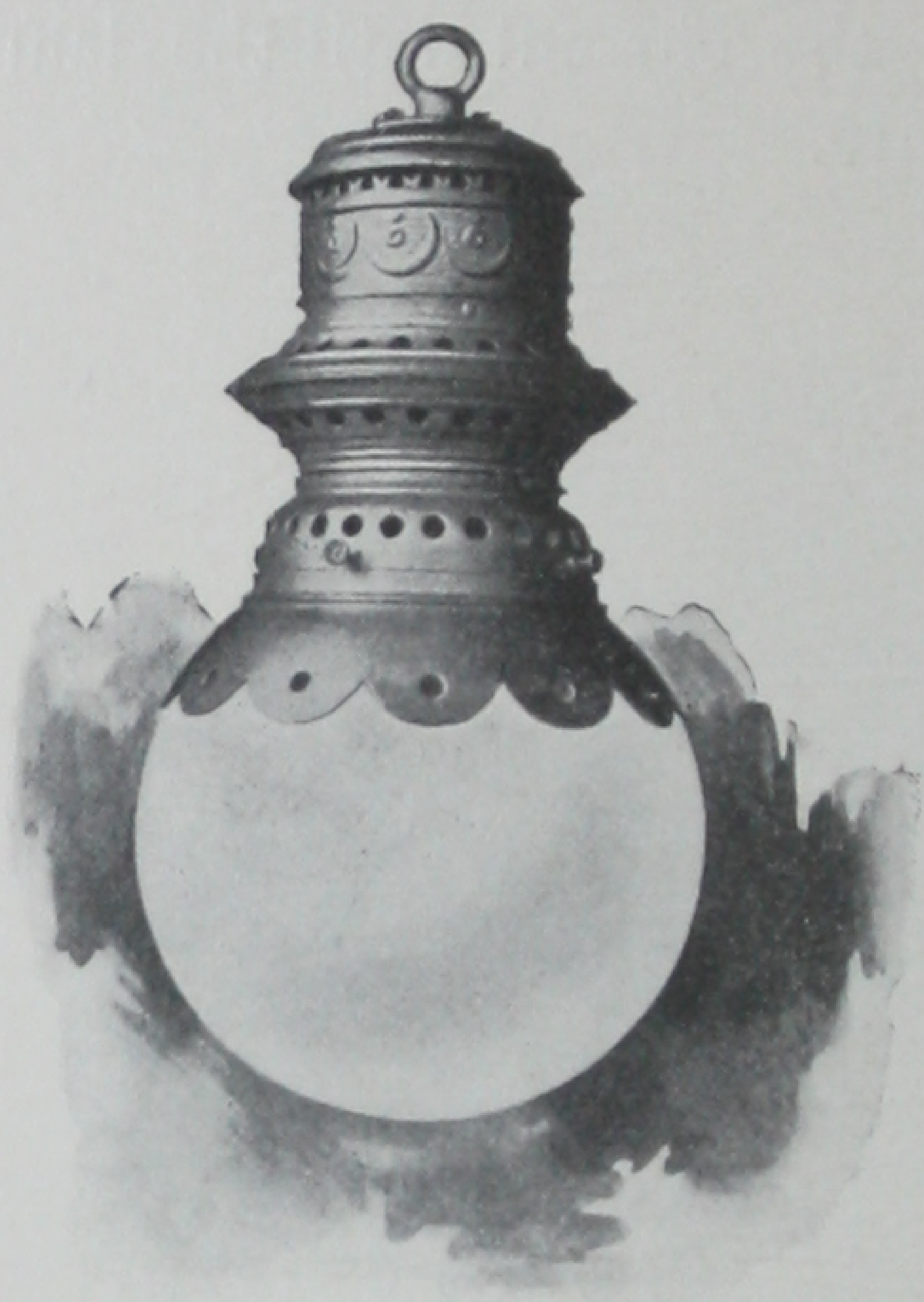

Fig. 14.—Two and three glower lamp, indoor type.

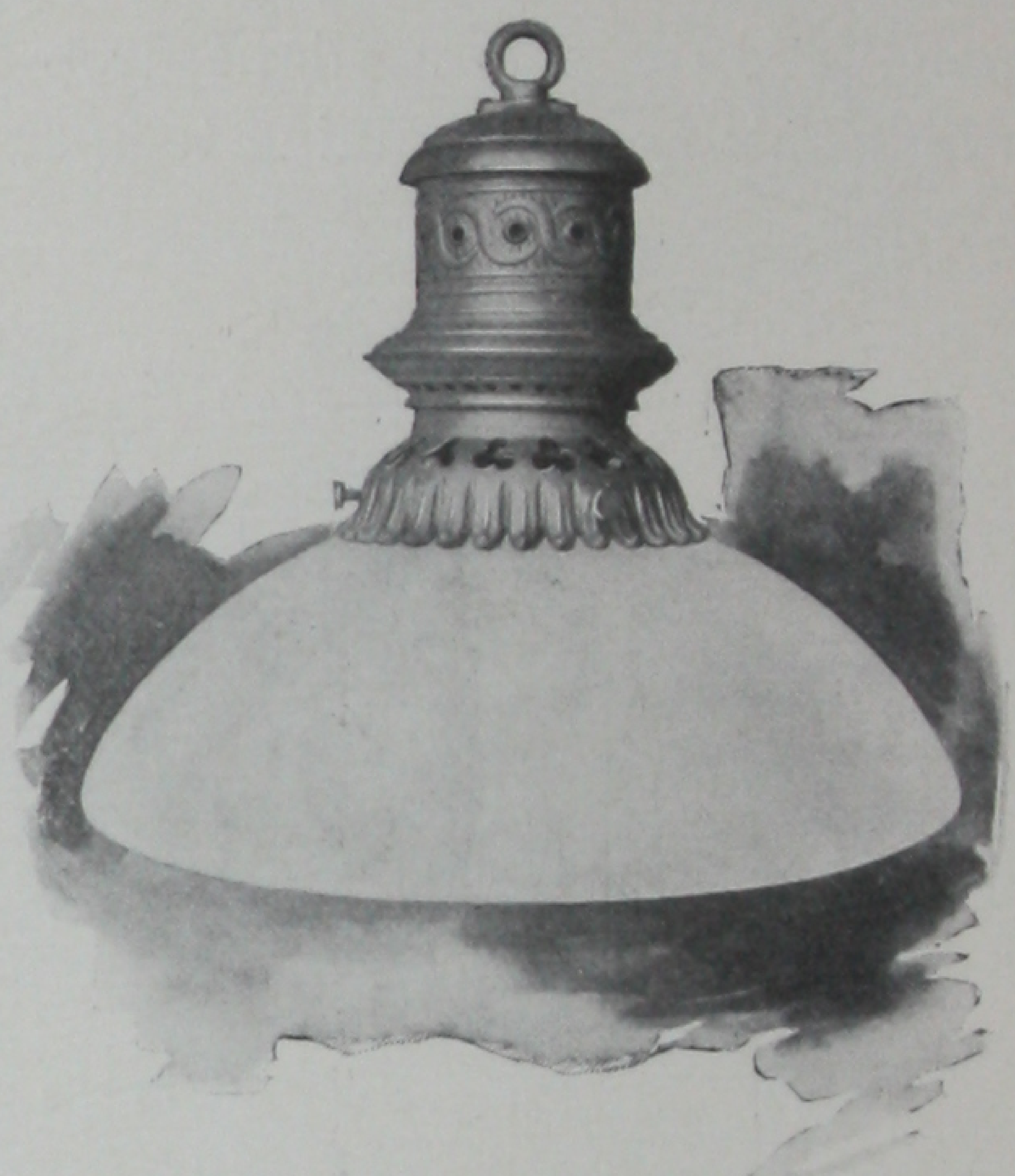

Fig. 15.—Six glower lamp, indoor type.

and our experience shows an average life of 800 hours for the glowers, 2,000 to 3,000 hours for the heaters and an indefinitely long life for the ballasts. It will, however, be some time before the average life of the heaters and ballasts can be definitely determined. The attention which these lamps receive, consists in having the inspector examine the lamps once a week through a colored glass to determine whether or not all six glowers are burning. If two glowers are out, the lamp is turned off, the holder removed and two new glowers inserted; the holder is then returned to its place and the lamp continued in service. Aside from such renewals, these lamps have not given the least trouble.

On the occasion of starting up 50 six-glower lamps at East Pittsburg, one of the engineers who had had considerable experience with arc lamps, remarked that my troubles would now begin; but, frankly, I think he was mistaken. Aside from the renewal of the perishable parts, I see nothing in the lamp which

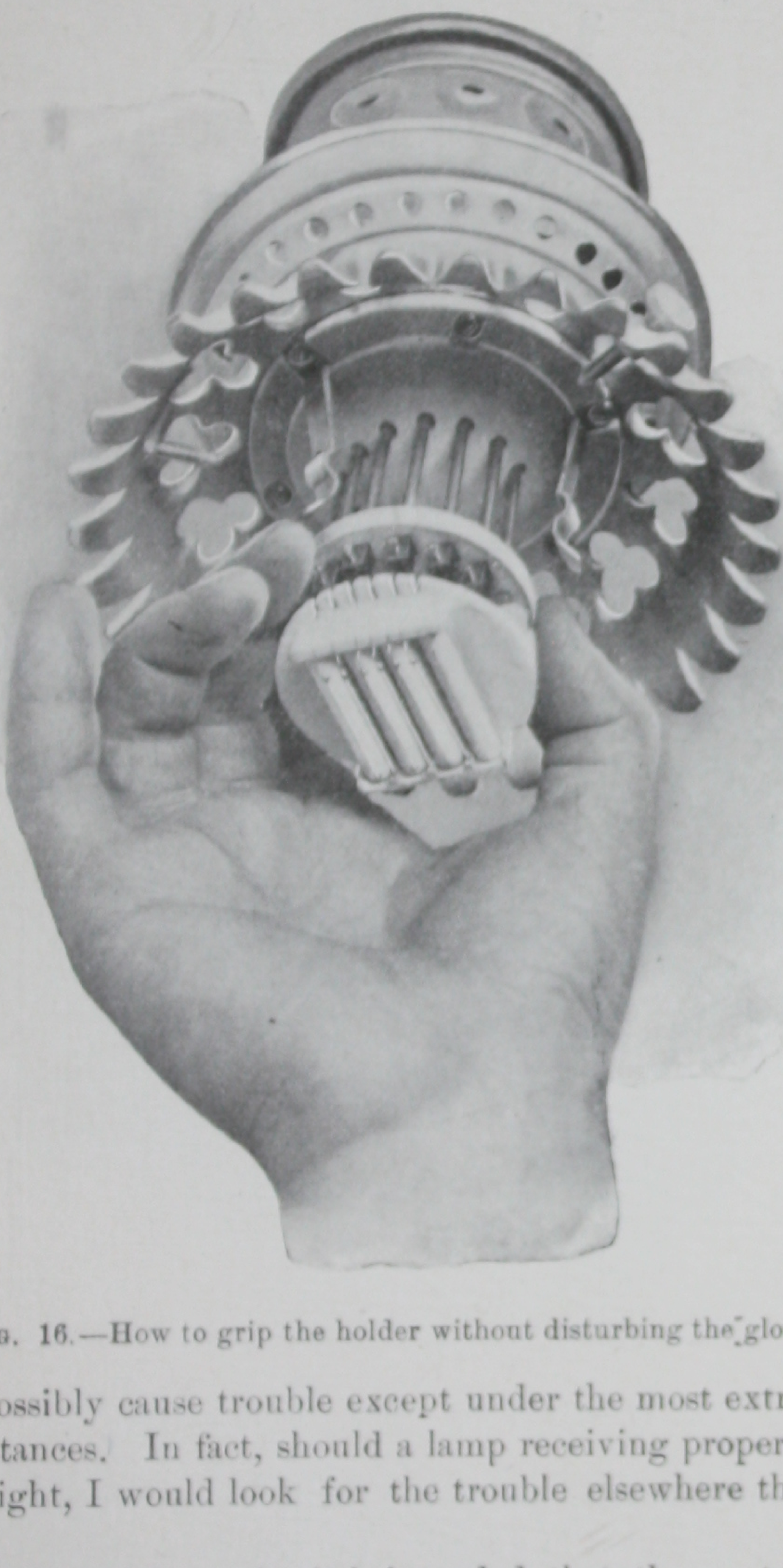

FIG. 16.—How to grip the holder without disturbing the glowers.

could possibly cause trouble except under the most extraordinary circumstances. In fact, should a lamp receiving proper attention fail to light, I would look for the trouble elsewhere than in the lamp.

In commercial service it is intended that the central station shall make the renewals in the holders. The customer will be

provided with a case containing a suitable number of complete holders, ready for service, so that when a renewal is to be made, the customer will simply remove the old holder and insert a new one, such operation consuming but a moment's time; then, at

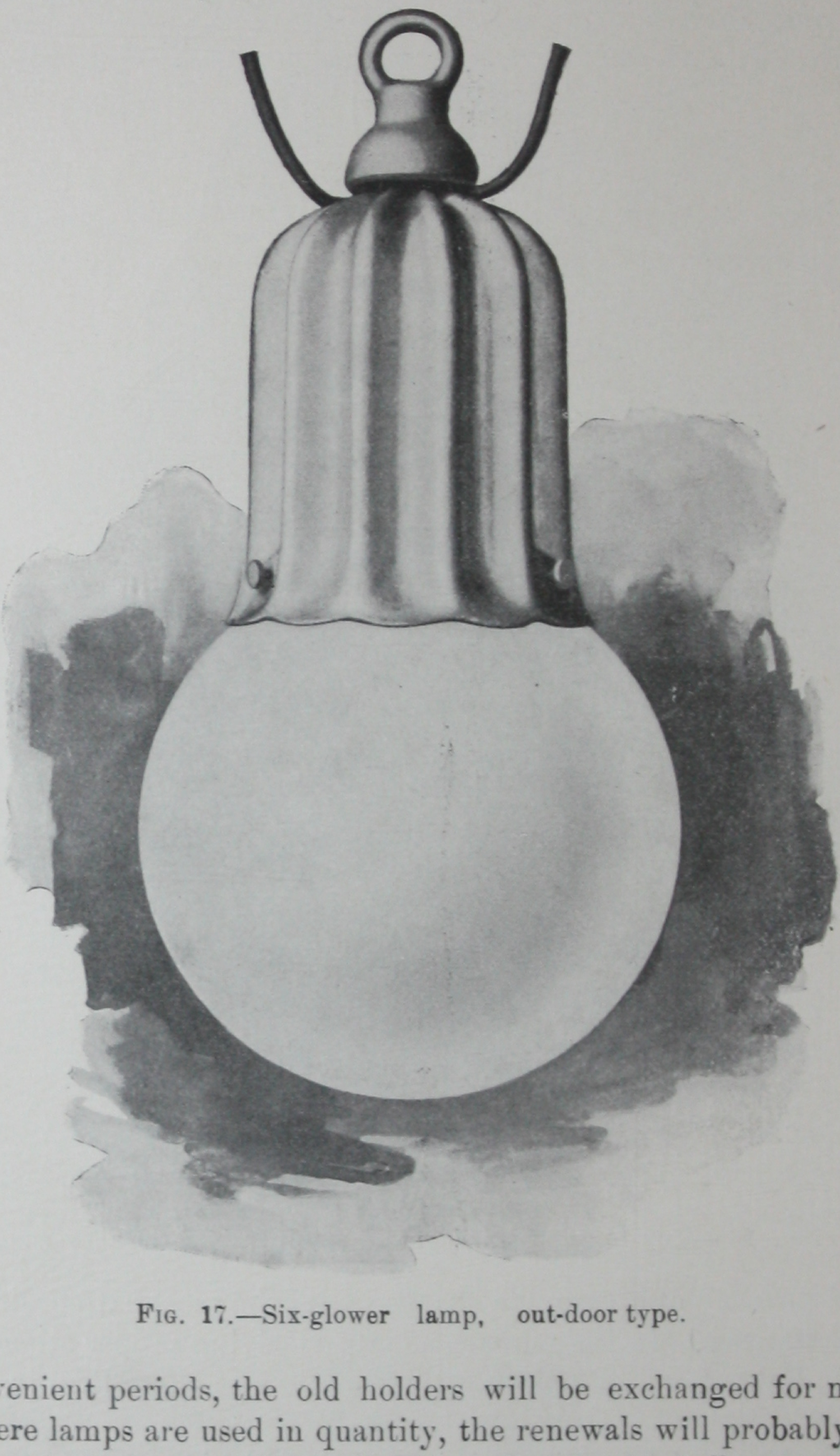

Fig. 17.—Six-glower lamp, out-door type.

convenient periods, the old holders will be exchanged for new. Where lamps are used in quantity, the renewals will probably be made by the local attendant. The replacing of a ballast requires

the removal of the lamp from the circuit, but after that the renewal is easily and quickly made. A slight withdrawal of one screw releases the ballast tube from its socket, whereupon the small aluminium terminal plugs may be withdrawn and the new ballast inserted. This operation does not require any tools other

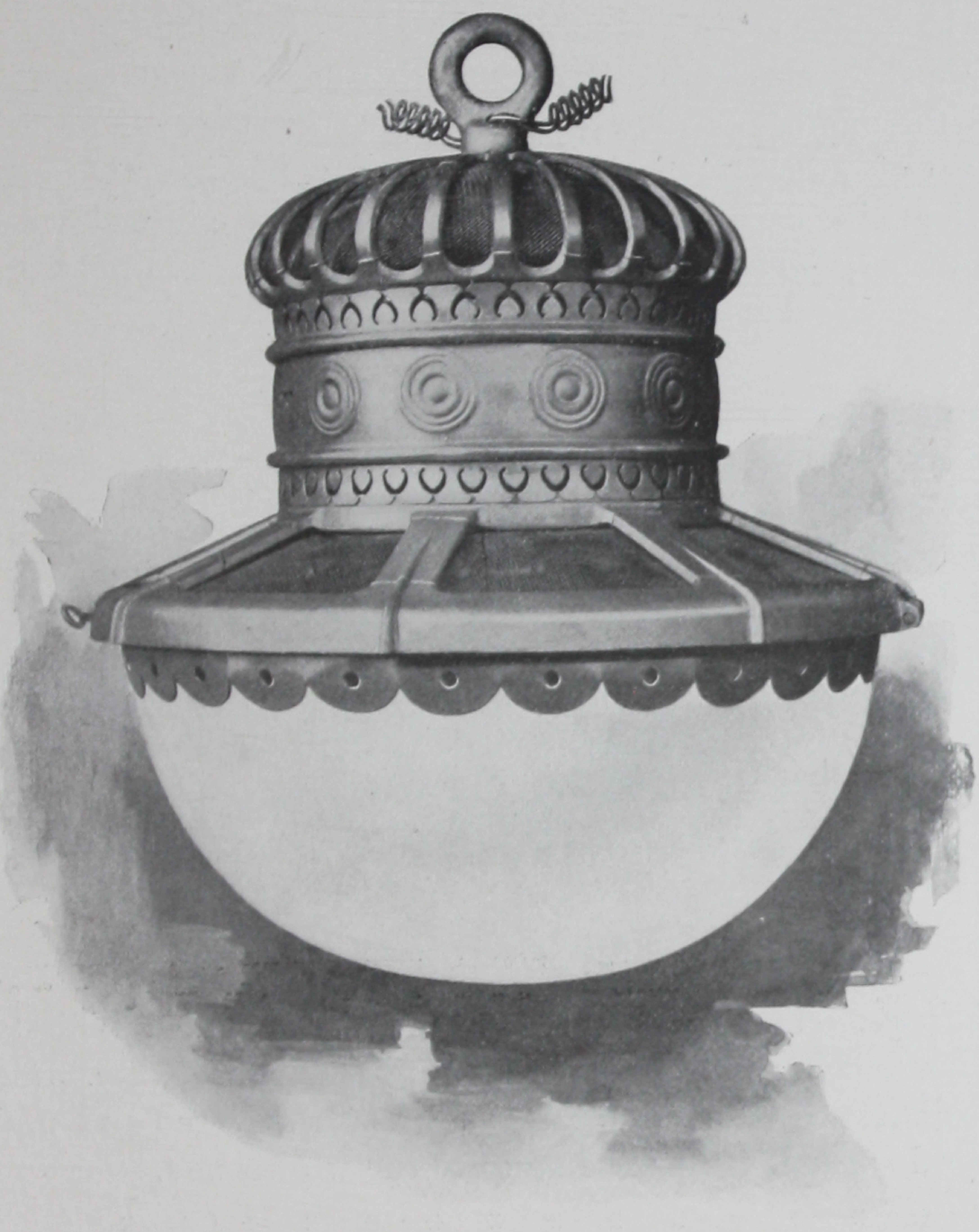

FIG. 18.—Thirty-glower lamp, indoor type.

than a pair of small tweezers, and the renewal can be made without returning the lamp to the workbench.

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The following instructions for the care and inspection of the Nernst lamps are observed at East Pittsburg:

Inspection of the Lamps.—The lamps should be inspected every 100 lamp hours. After being turned off, the lamp is turned on, and it is noted whether all the heater tubes become

bright. If any of the heater tubes are burned out, the holder is replaced by a new one.

If the heaters are intact, the number of glowers burning is determined. If five or six are burning, the lamp needs no attention.

If less than five glowers are burning, the lamp is to be turned off, the holder taken out and the number of broken glowers determined by inspection. If the number of broken glowers is less than the number of glowers that were out, one or more ballasts are out of order and the lamp is to be taken down at once and the defective ballast replaced. When two or more glowers are burned out, the holder is to be replaced by a reserve holder.

FIG. 19.—Single glower lamp, indoor type.

Ballasts.—These are supplied in boxes marked "Ballasts for six-glower lamps," "Ballasts for one-glower lamps," etc. Burned out ballasts are to be renewed as soon as discovered and may be replaced without taking the lamp to the workbench.

* * * * * * * * * * * * * * *

Glowers.—These are supplied in glass tubes marked with the voltage of the lamp for which the glower is intended, thus, "Glowers for 220-volt, six-glower lamps." Glowers marked for six-glower, are not to be used in a three or one-glower lamp and vice versa.

Heaters.—These are wound for 110 volts and are so marked. They are connected two in series for 220 volts. In the six-glower lamp there are four tubes connected in multiple series.

Heater Porcelain.—(This is the porcelain disk immediately behind the heater.) The heater porcelain is given a white coat-

ing which becomes fairly hard, but can be easily scraped or brushed off when it becomes covered with platinum back. When a holder with a black heater porcelain is removed, the glowers should be taken out, the old coat brushed off, except directly under the heater tubes, and a new coat of "heater porcelain paste" applied. This paste is a white powder which is to be mixed with water and applied with a camel's hair brush. After replacing the heater porcelain and allowing it to dry in the air, run the heater for two minutes on 220 volts, placing the holder in a heater case. This hardens the coating, after which the glowers may be replaced.

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Conclusion.

In closing, let me say that the Nernst lamp can in no sense be considered an experimental device. The development of details connected therewith has continued until all question of doubt as to its commercial success has been removed by the operation of a large number of lamps of various sizes and finished pattern for extended periods under commercial conditions, and it is confidently felt that the splendid exhibit of these lamps which may be seen at the Pan-American Exposition will prove a fitting demonstration of the complete and thorough manner in which the brilliant discovery of Dr. Nernst has been taken up and pushed forward in America.

Note.—There are now, February 1902, in regular commercial service, more than 300,000 candle-power in Nernst lamps.—N. L. Co.

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